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(54) **METHOD FOR THE MANUFACTURE OF A HOLE IN A COMPONENT CONSISTING OF A COMPOSITE MATERIAL**

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**B26F 1/24** (2013.01); **B26F 2001/4427**  
(2013.01)

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**B26F 2001/4427**; **B29C 37/00**; **B29C 51/42**;  
**B26D 7/20**

USPC ..... **264/280**, **284**, **156**, **293**, **479**, **155**, **383**;  
**83/30**

See application file for complete search history.

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*Primary Examiner* — James Sanders

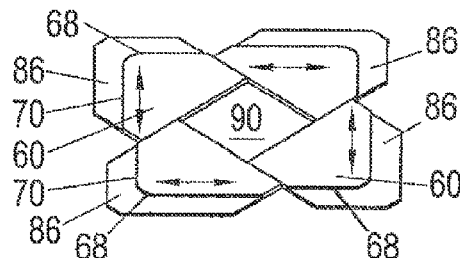
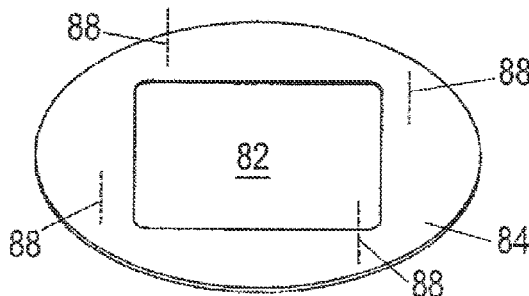
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(57) **ABSTRACT**

A method for the manufacture of a hole in a component consisting of a composite material, such as a fiber reinforced plastic part or a fabric reinforced plastic part, which is characterized in that the component having first and second oppositely disposed sides is placed with its first side on a support having an iris diaphragm, in that a tip which diverges in the axial direction is pressed coming from the second side of the component through the component, which optionally has a pre-piercing, for the formation of the hole or for the enlargement of the pre-piercing and in that the iris diaphragm has a smaller starting opening which receives a narrower region of the tip and opens into a larger opening with increasing penetration of the component by the tip, whereby the component is supported during the hole formation over an as large as possible area from the first side. A piercing aid in the form of an iris diaphragm or a corresponding die button is likewise claimed.

**6 Claims, 8 Drawing Sheets**



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(56)

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Fig. 1A

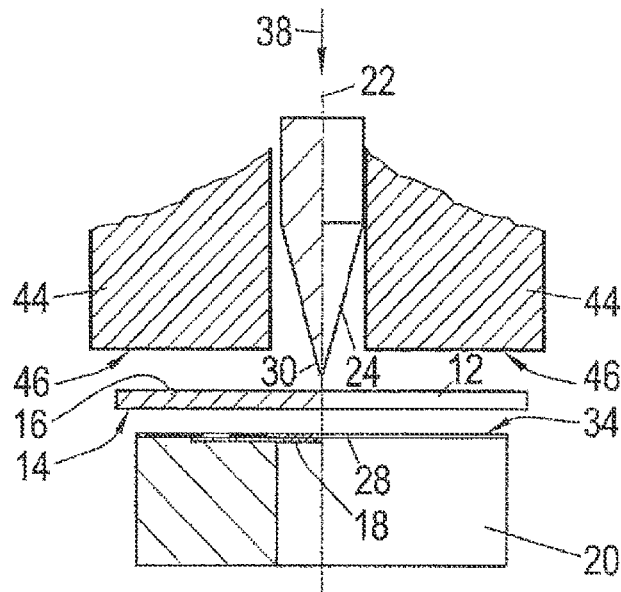


Fig. 1B

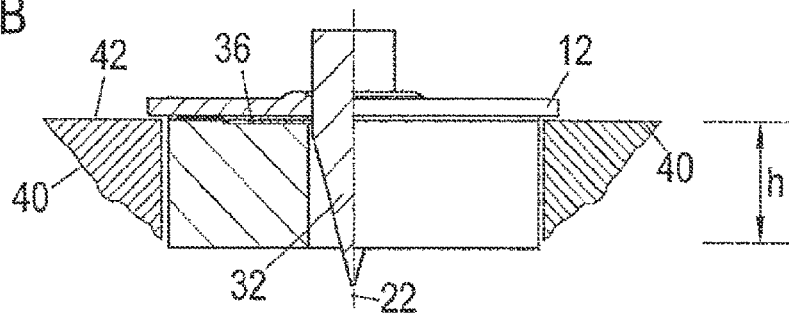


Fig. 1C

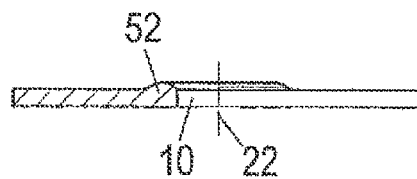


Fig. 2A

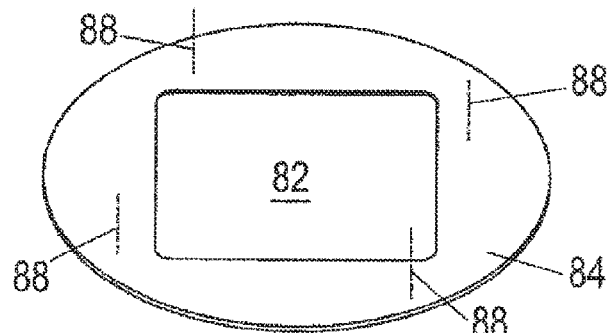


Fig. 2B

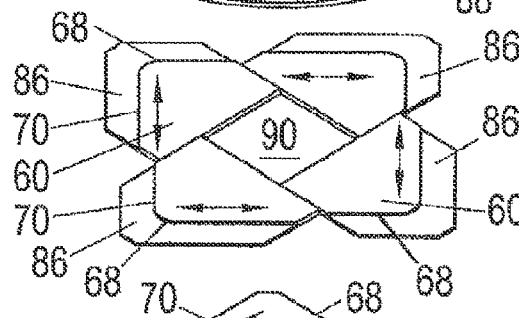


Fig. 2C

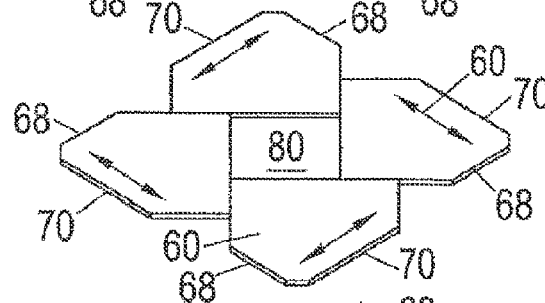


Fig. 2D

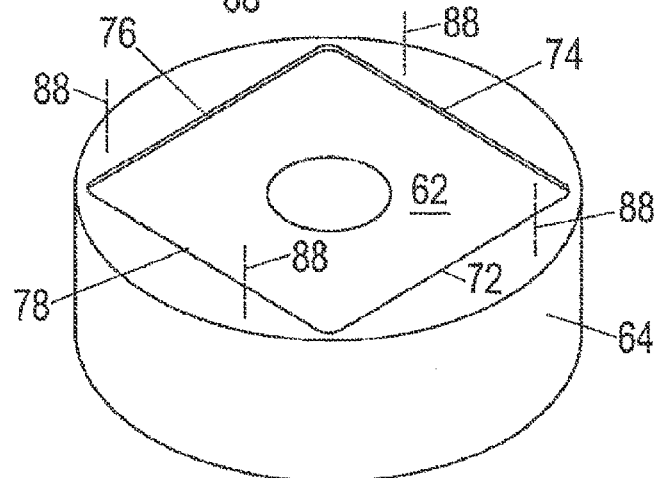


Fig. 2E

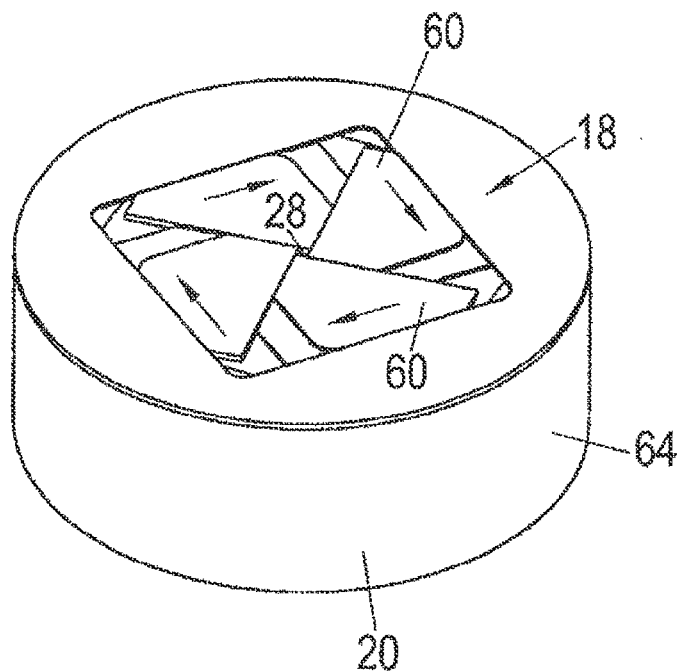
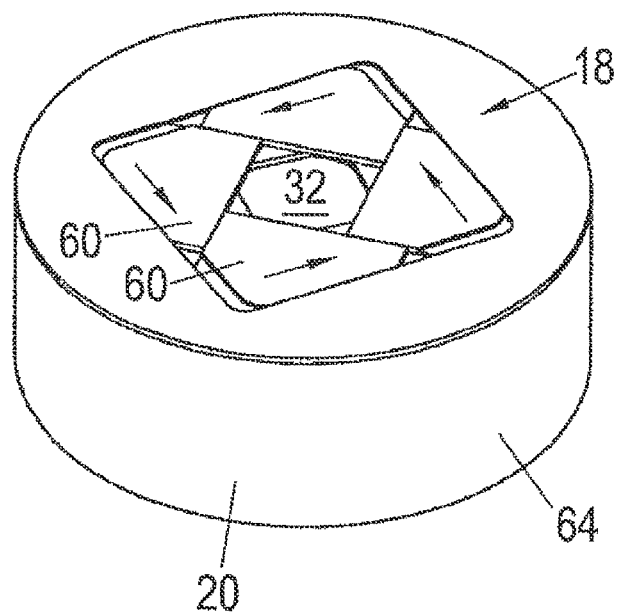


Fig. 2F



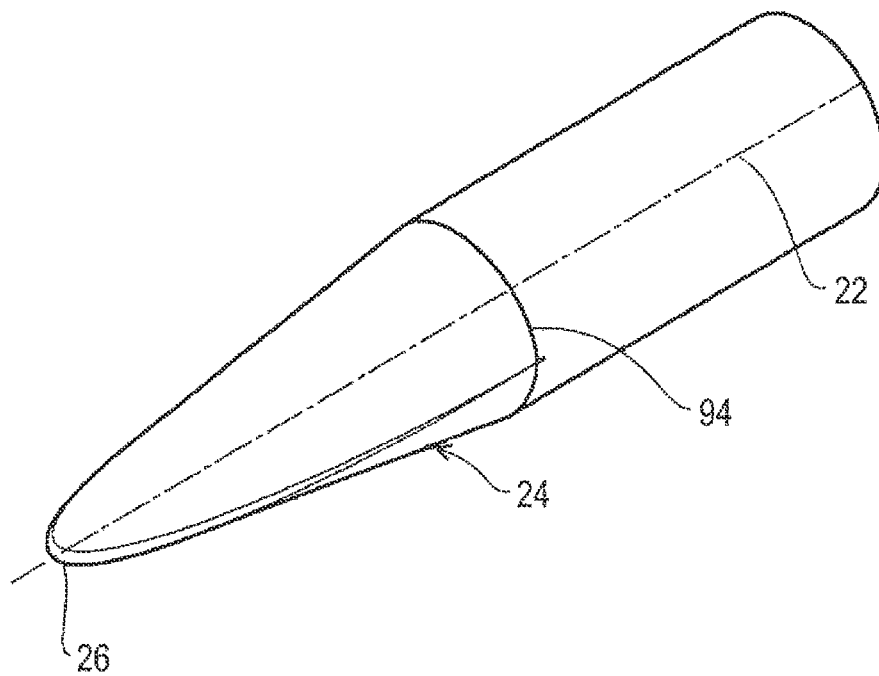


Fig. 3A

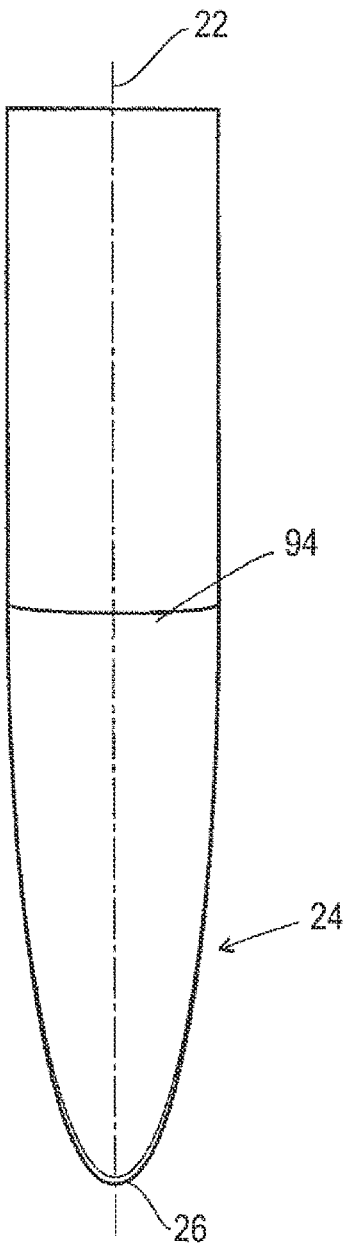


Fig. 3B

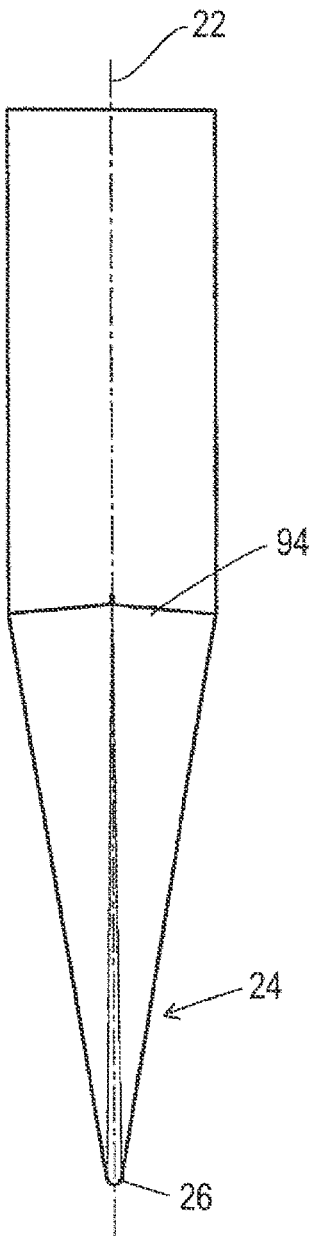


Fig. 3C

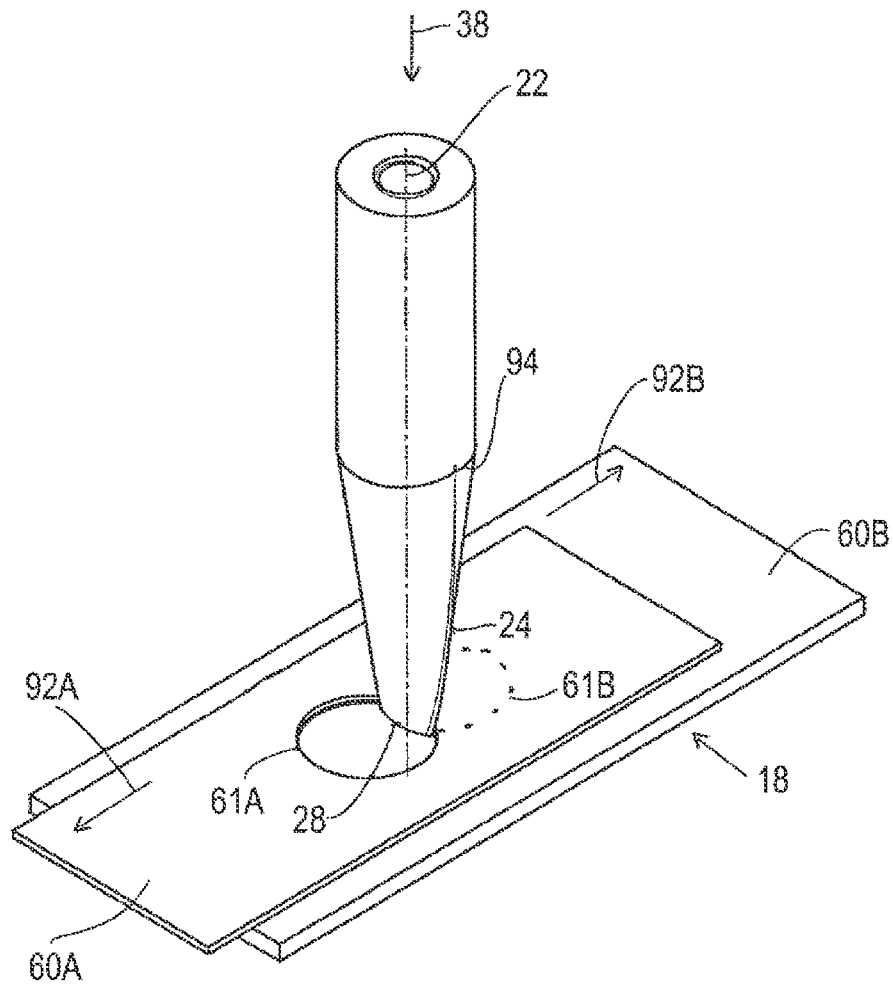


Fig. 4A



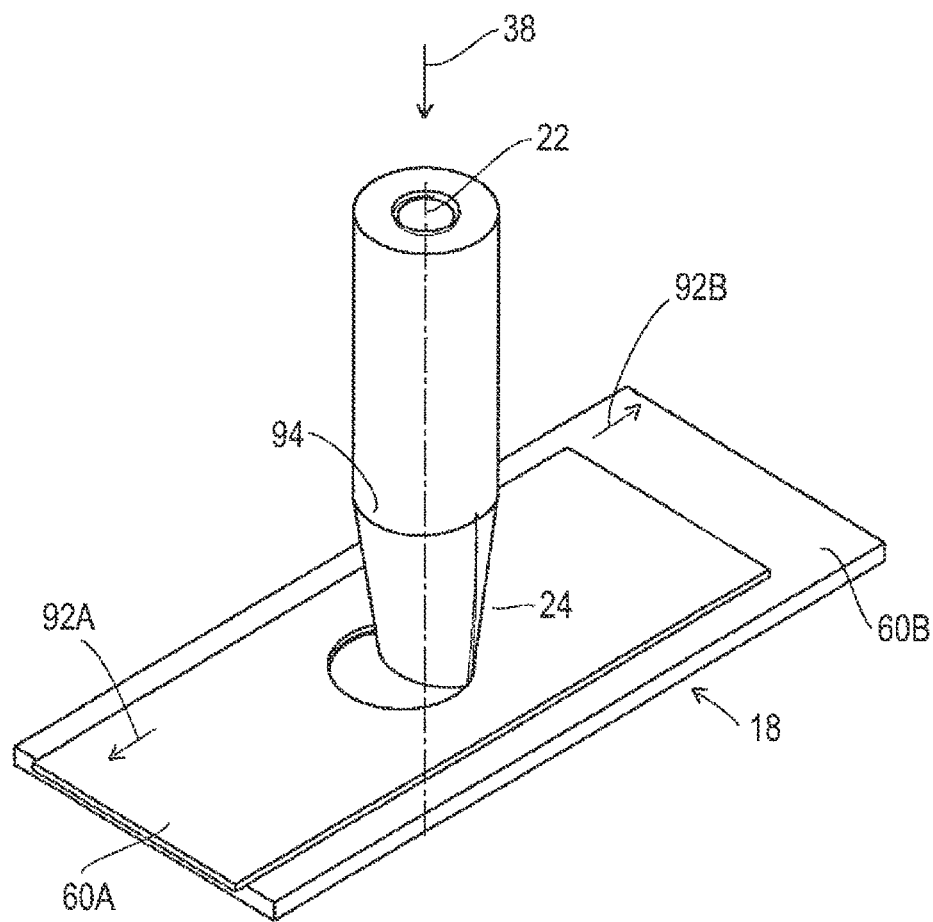
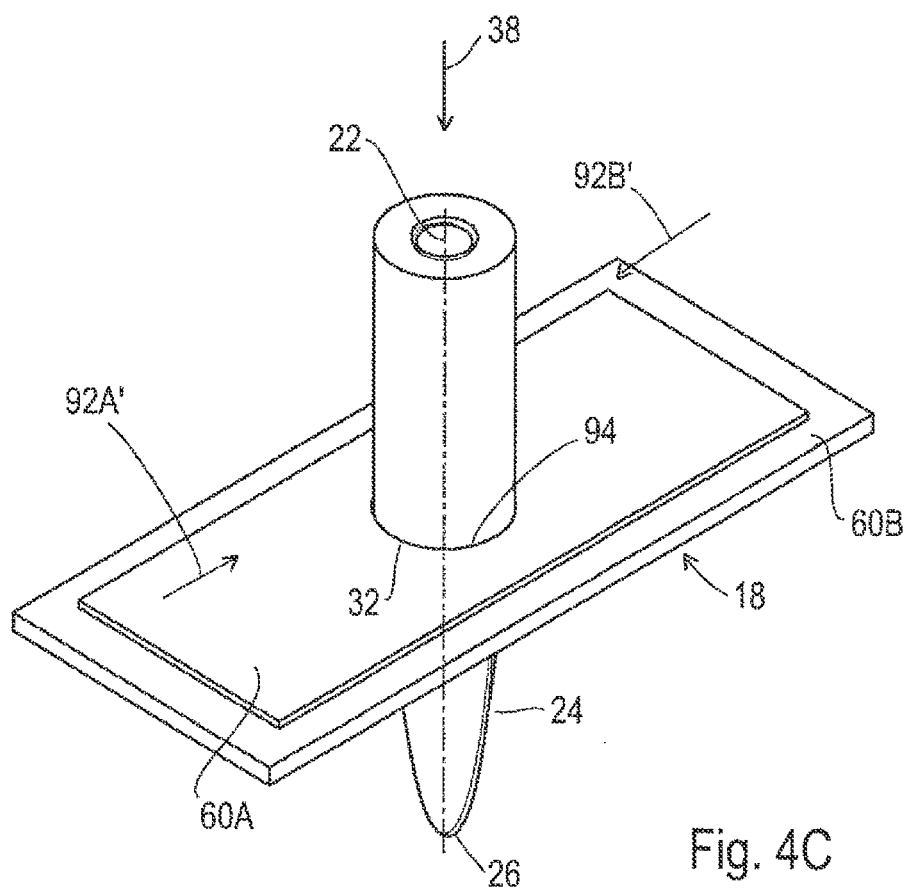


Fig. 4B



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# METHOD FOR THE MANUFACTURE OF A HOLE IN A COMPONENT CONSISTING OF A COMPOSITE MATERIAL

## CROSS-REFERENCE TO RELATED APPLICATIONS

The present application claims priority under 35 U.S.C. §119 to German Patent Application No. 10 2012 001 067.2, filed on Jan. 20, 2012 and German Patent Application No. 10 2012 209 599.3, filed on Jun. 6, 2012, the disclosures of which are expressly incorporated by reference herein in their entireties.

## FIELD OF THE INVENTION

The present invention relates to a method for the manufacture of a hole in a component consisting of a composite material such as a fiber reinforced plastic part or a fabric reinforced plastic part and also a piercing aid for this purpose.

## BACKGROUND OF THE INVENTION

Composite materials are frequently used in the most diverse areas and consist mainly of plastic with embedded fiber reinforcement which are amongst other things also known in the form of tapes, fabrics, felts and mats. For example, coachwork parts of polyester resins reinforced with glass fibers and plastics, such as epoxy resins reinforced with carbon fibers, are frequently used in motor car construction. Numerous further components, such as consoles and cladding, are likewise also manufactured from such composite materials. When using carbon fibers as a reinforcement, fabrics of carbon fibers are frequently used because one can then obtain a reinforcement in all directions of the component.

The field of composite materials is, however, in no way restricted to glass fibers and carbon fibers there are many other reinforcement fibers which can be considered. Furthermore, the most diverse plastics can also be used as a matrix material. All such materials are described here generically as composite materials and fiber reinforced plastics. They can also be described by the generic term "organic sheet metals". This term is understood in some circles as a specialist term.

Composite materials are composed of an arbitrary reinforcement material or fibers and an arbitrary, plastically deformable or meltable matrix material. The term "composite material" is used here in accordance with the invention and for this reason not only comprises plastics with fiber reinforcement, but, for example, also comprises matrix materials of metal, e.g. aluminum with a reinforcement material, such as e.g. carbon fiber or ceramic particles.

## SUMMARY OF THE INVENTION

The present invention primarily uses those composite materials which use a thermoplastic material, i.e. a thermoplastic as matrix material which softens or becomes pasty at elevated temperatures lying below the melting point. It is, however, not precluded that duroplastics can also be used as a matrix material provided these are adequately soft or become soft or pasty at elevated temperatures, i.e. at temperatures which lie beneath the temperatures at which the matrix material is permanently damaged. The method claimed here can also be used for composite materials with matrix materials which are indeed not thermoplastics but have not yet reached their final state but rather are present in a state in which they soften with or without heating but which can be transferred

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into a harder state in the course of time or by the action of ultraviolet light or humidity or otherwise through progressive polymerization or cross-linking.

It is frequently necessary to use components of composite materials with fastener elements, for example, in order to secure the corresponding components to other parts or to attach other parts to the fiber reinforced plastic components.

Both rivet elements and also bolt or nut elements can be considered which can all be subsumed under the term functional elements. This term applies also for clips and bearings which can likewise be secured to composite materials. Irrespective of what form such functional elements have it is always necessary to provide a hole or a plurality of holes to a plastic part in order to enable the attachment of the respective desired functional element, unless threaded inserts or eyes are integrated into the plastic component during the manufacture of the component, which is, however, very time consuming and complicated and leads to further costs and sometimes makes a local thickening of the plastic part necessary. The manufacture of holes is mainly achieved by a drilling process, whereby material residues, such as cuttings, arise and the composite material is weakened in the region of the bore. It is also conceivable to punch the component in order to generate the holes as required, whereby waste in the form of punching slugs which has to be dispensed of arises as well as a local weakening of the component.

The object of the present invention lies in providing a method and piercing aid which enable the provision of holes in a component at least in a substantially loss-free manner without pronounced weakening of the component, in particular holes for the reception of functional elements such as rivets, rivet bolts and rivet nuts and also bolt elements and nut elements in general.

Furthermore, a pronounced weakening of the component in the area of the hole should not only be avoided but rather a reinforcement of the region of the hole should preferably take place.

In other respects, the method should be capable of being carried out in a cost-favorable manner and the piercing aid should be capable of being realized in a cost-favorable manner.

In order to satisfy this objects, a method of the initially named kind is characterized in that that the component having first and second oppositely disposed sides is placed with its first side on a support having an iris diaphragm, in that a tip which diverges in the axial direction is pressed coming from the second side of the component through the component, which optionally has a pre-piercing, for the formation of the hole or for the enlargement of the pre-piercing and in that the iris diaphragm has a smaller starting opening which receives a narrower region of the tip and opens into a larger opening with increasing penetration of the component by the tip.

As a result the component is supported during the hole formation over an as large as possible area from the first side. When it is said that the tip diverges in the axial direction this will be understood to mean that the tip diverges in a rearward direction starting from the front end or apex of the tip, which is generally a point or a sharp or rounded apex.

The corresponding piercing aid for the formation of a hole in a component consisting, in particular of a composite material, such as a fiber reinforced plastic part or a fabric reinforced plastic part is characterized in that the piercing aid is an iris diaphragm having a smaller initial opening which can be pressed apart to a larger opening.

Thus, in accordance with the invention, the component of a composite material is provided with a hole by means of a tip which is pressed through the component while the component

is supported from the underside and indeed in the region of the piercing always directly adjacent to the tip so that as little composite material as possible can escape between the side-wall of the tip and the periphery of the hole, since the opening of the iris diaphragm always adapts to the respective diameter or the respective cross-sectional shape of the tip in the area of the enlarging hole.

Since a tip is used, the fiber reinforcement in the region of the hole is not destroyed to a considerable extent as is the case during drilling or punching, but rather at most only a few fibers are parted and the material, which is normally cut out is, in accordance with the invention, displaced to the side and forms a thickened region there which is likewise reinforced with fibers. Thus, in the region of the hole, and around this a fiber reinforced thickening of the component automatically arises. In this way forces can better be introduced from the functional element into the component without fatigue or crack formation having to be feared in the region of the peripheral hole. Furthermore, no lost material arises which has to be disposed off and no dangers to health arise from free sharp fiber residues because these do not arise.

It is indeed entirely possible to carry out the entire piercing method with the aid of the tip and the iris diaphragm, it is, however, not precluded that a pre-piercing is effected. For example, pre-piercing of this kind could be effected during manufacture of the fiber reinforced component in a press or in a drilling process, for example, then when a type of pre-positioning or pre-centering of the fiber reinforced component relative to another component or vice versa has to be ensured by the pre-piercing.

An iris diaphragm is preferably used which forms a part of a die button received in the support with the end face of the die button confronting the component either being flush area-wise with the local plane of the support or arranged set back from the latter.

The this flush area-wise alignment is favorable because the fiber reinforced plastic material cannot escape downwardly but rather the aforesaid thickening takes place at the upper side of the component, the fiber reinforced plastic swells so to say there. The full area support of the component in this region also has the advantage that the diaphragm segments of the iris diaphragm are better supported against tilting movements. A slightly set back arrangement of the iris diaphragm or of the end face of the die button is, however, useful under some circumstances, for example when the thickened portion is desired at the lower side of the component. Provision should then, however, be made that the fiber reinforced plastic part is not sheared at a peripheral edge, for example by provision of a rounded edge and that the diaphragm segments are secured against a tilting movement, for example, in that the surface of the supported regions of the diaphragm segments aperture of the die button are made significantly larger than the surface in the region of this aperture or in that the segments have external shoulders which are arranged flush area-wise with the support.

When here there is talk of "underside" and of a "support" or of "supporting" this is only related to a representation of the component and indeed in such a way that this is arranged above the support or the iris diaphragm or supported there, as shown in FIG. 1 at the bottom. In practice, the component could have any desired orientation, for example, such that the support is arranged above the component and the tip is arranged coming from below or indeed such that the component has any desired inclined position.

The force which is exerted on the tip can be applied in a press, by tongs, by a robot, by means of a C-frame with power unit or in a tool such as an arbor press or pillar drill (drill press) or otherwise.

The iris diaphragm is preferably automatically reset after each piercing of the component from the larger opening to the smaller opening.

It is particularly favorable when the component is heated, at least in the region of the piercing, to a matrix material dependent temperature at which the matrix material of the composite material is not melted, but softens or becomes pasty, for example, at a temperature of 260° when the material is PA6.

The auxiliary means, such as a piercing aid, for the hole formation in a component consisting in particular of a composite material is preferably characterized in that the iris diaphragm has at least two to twelve movably arranged diaphragm segments which are arranged in one plane or in a plurality of planes or preferably in two planes.

It is sufficient, when two mutually displaceable diaphragm segments are provided. Problems such that the fiber reinforced plastic material escapes at the diaphragm segments in the region of the respective cross-section of the tip need not be feared. Two such diaphragm segments can be used when they, for example, each have a V-shaped opening which together form a square opening or each have a half hexagonal opening which jointly form a hexagonal opening. Both a square opening and also a hexagonal opening represents a not unreasonable adaptation to a circular shape and indeed such that a respective opening of the iris diaphragm grows with the circular shape of the tip during the progressive penetration of the tip. It is, however, somewhat problematic that with two overlapping diaphragm segments these must at least partly lie in two planes, whereby a step is formed which can lead to a corresponding step in the component. The diaphragm segments can, however, be made relatively thin and a step of this kind can be kept very small.

The movably arranged segments are preferably guidedly arranged in a mount or in a plurality of mounts of a die button body. In this way the diaphragm segments can be accommodated in the well ordered manner secured against loss and can also be synchronizably guided and resiliently resettable.

For this purpose, an arrangement of the diaphragm segments in two planes in one mount can be formed in the end face of a die button body confronting the component and a second mount can be formed in a disk which is to be arranged or is arranged on the end face of the die button body or recessed within it. This represents a simple but effective possibility for accommodating the diaphragm segments in two planes. The use of a disk for one mount permits a rotation of this mount relative to the mount in the die button body which is particularly favorable, as has already been explained.

The diaphragm segments of the iris diaphragm are preferably each biased into a position in which they form the smaller starting opening. A bias of this kind ensures that after a piercing process, which is, for example, brought about by means of a stroke of a press or of another tool, the iris diaphragm automatically adopts the starting position for a further piercing process with a new component and with a further stroke of the tool.

A device is preferably provided which synchronizes the movement of the diaphragm segments. In this way it can be ensured that the respective opening or size of the opening of the iris diaphragms is matched to the respective cross-sectional shape and cross-sectional size of the tip.

For this purpose a plurality of possibilities are available. For example, the synchronization device can be formed by the

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tip which itself broadens in the axial direction when the guidance of the diaphragm segments is effected, such that they are guided by the peripheral wall of the mount or otherwise under the pressure which is exerted from the inside by the tip.

Pins can also be attached or provided at the diaphragm segments which are guided in corresponding bores in the sidewalls of the mounts.

A compulsory guidance may be considered for the synchronizing device which is movable synchronously with the hole formation. For example, a rotary ring with pins which engage in curved spiral groove segments of the diaphragm segments can be rotated synchronously with the axial movement of the tip by means of a suitable stepping motor or mechanical mechanism.

It is particularly favorable when the diaphragm segments lie in a first and in a second plane, the diaphragm segments of the first plane form a substantially polygonal hole, the diaphragm segments for the second plane form an at least substantially polygonal hole and the polygonal hole of the first plane is offset relative to the polygonal hole of the second plane by one half side length of the polygonal hole.

With an arrangement of this kind, a hexagonal opening can be formed by the iris diaphragm or the diaphragm segments using three diaphragm segments in each of the two planes, which represents a good approximation to a circular cross-section of a conical tip. With four diaphragm segments in each plane an octagonal opening of the iris diaphragm can be realized which enables an even better approximation to the circular cross-section of a conical tip.

With an arrangement of this kind having four diaphragm segments in each plane the diaphragm segments of each plane are arranged in an at least substantially square mount and each diaphragm segment can be executed, apart from the rounded corner regions, with four straight sides and indeed two longer and two shorter sides of which a first pair form a right angle with one another and a second pair form a right angle with one another with two further enclosed angles of the four enclosed angles of the diaphragm segments amounting to 45° and 135°.

It is particularly favorable when a piercing aid is provided in combination with a tip which is formed by the free end face of the shaft part of a pin or as an auxiliary tip, and with the combination being characterized in that a cross-sectional shape and cross-sectional size of the tip or of the auxiliary tip in the longitudinal direction of the tip or of the auxiliary tip is always matched to the respective cross-sectional shape and cross-sectional size of the widening opening of the iris diaphragm.

Expressed differently, the adaptation of the cross-sectional shape and cross-sectional size of the tip to the cross-sectional shape and cross-sectional size of the opening of the iris diaphragm takes place such that independently of the degree of penetration of the iris diaphragm by the tip or auxiliary tip, the cross-sectional shape and cross-sectional size of the tip or of the auxiliary tip in the region of the opening of the iris diaphragm always corresponds to the cross-sectional shape and cross-sectional size of the respective opening.

As a result of this design the cross-section of the tip or of the auxiliary tip always fills the respective opening of the iris diaphragm, such that no corner or other regions of the respective opening exist through which material of the composite material can escape through the iris diaphragm.

The concept as just explained can be particularly advantageously realized when the iris diaphragm is equipped with two diaphragm segments and the tip or the auxiliary tip has a duck-beak shape. With such an embodiment the diaphragm segments can each be formed by a plate having a circular hole,

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with the one plate being slidable on the other plate. An arrangement of this kind can be particularly favorably realized because the corresponding holes only have to be drilled or punched out. Moreover, the plates only have to slide relatively to one another in one direction, whereby both the guidance of the plates and the resetting of the plates can be realized particularly simply.

## BRIEF DESCRIPTION OF THE FIGURES

The invention will be explained in more detail in the following with reference to an embodiment with respect to the drawing in which are shown:

FIGS. 1A to 1C a series of drawings for representing the principle of the method in accordance with the invention with the respective three phases of the method,

FIGS. 2A to 2F a series of drawings for illustrating the principle of a design of a piercing aid in accordance with the invention in the form of a die button having an iris diaphragm with a perspective illustration of an upper disk (FIG. 2A), a perspective illustration of a first arrangement of four diaphragm segments (FIG. 2B), a perspective illustration of a second arrangement of four diaphragm segments (FIG. 2C), a perspective illustration of a die button body (FIG. 2D) and with a perspective illustration of the assembled die button with the iris diaphragm in a closed position (FIG. 2E) and in an opened position (FIG. 2F),

FIGS. 3A to 3C an embodiment of an auxiliary tip in accordance with the invention in a perspective representation (FIG. 3A) in a plan view onto the side of the auxiliary tip (FIG. 3B) and in a side view (FIG. 3C) perpendicular to the plan view of FIG. 3B, and

FIGS. 4A to 4C three phases of the piercing of the composite material with the aid of the auxiliary tip in accordance with FIGS. 3A to 3C.

## DETAILED DESCRIPTION OF THE INVENTION

Referring to FIGS. 1A to 1C the method for the manufacture of a hole 10 in a component 12 consisting of a composite material, such as a fiber reinforced plastic part or a fabric reinforced plastic part, will be explained in more detail. The component 12 has first and second oppositely disposed sides 14 and 16 and is supported at its first side 14 on a support 20 having an iris diaphragm 18. A tip 24 which becomes progressively broader in the axial direction 22 is pressed through the component 12 (which may have a pre-piercing—which is however not shown) for the formation of the hole 10 or for the dilation of the pre-piercing. The iris diaphragm 18 has a smaller initial opening 28 which receives a narrower region of the tip 24 and which transforms with progressive penetration of the component by the tip into a larger opening 32, whereby the component is always supported over the fullest area possible during the hole formation from the first side 14, partly by the end face 34 of the support 20 and partly by the upper side of the diaphragm segments 36 of the iris diaphragm.

The force which is exerted in the direction of the arrow 38 onto the tip can be applied in a press, by a pair of tongs, by a robot, by means of a C-frame with a power unit or in another tool such as an arbor press or pillar drill (drill press) or otherwise. In this connection the support 20 is supported on a base plate of the corresponding tool or the like and the component is pressed under the pressure of the tip against the upper side 34 of the die button or of the diaphragm segments 36, as is shown in FIG. 1B.

A support 20 can, as shown, be formed by a die button or by a die button body alone, the die button can be incorporated

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into an opening of a table or of a lower tool, which is schematically drawn in chain-dotted lines **40** in FIG. **1B** and indeed preferably such that the upper side **34** of the die button lies flush area-wise with the local upper side **42** of the further support or of the tool **40**. This upper side of the further support of the tool **40** can also have a three-dimensional shape (not shown) matching a possibly present three-dimensional shaping of the component **12**.

Furthermore, the tip can be surrounded by a hold-down member **44** which, on the one hand, guides the tip and, on the other hand, is biased downwardly in FIG. **1A**, similar to a sheet metal hold-down member in the processing of sheet metal parts, so that the lower end face **46** of the hold-down member **44** presses the component **12** against the upper side **34** of the die button and/or the upper side **42** of the further support **40** and holds it non-shiftably during the piercing process.

The piercing process is carried out until the finished hole **10** (FIG. **1C**) corresponds to the desired diameter, which is normally the size of the tip in the cylindrical region **48**, but can, however, also be smaller if the stroke *h* of the tip is correspondingly restricted. The diverging shape of the tip **24** finally makes it possible to manufacture holes **10** in different sizes with one tip. It is simply necessary to appropriately select the stroke *h*.

The iris diaphragm **18** thus forms in this example a part of a die button **20** received in the support **40** with the end face **36** of the die button which confronts the first side of the component **12** lying flush area-wise with the local plane of the support **20** or **40** respectively.

Through the explained design of the method the front end or slightly rounded end of the tip **24** presses through the fiber reinforced plastic and displaces the plastic material with the reinforcement material embedded therein to the side and, since the component **12** itself does not permit any pronounced radial movement of the material, upwardly which leads to a thickened portion **52** and the reinforcement of the component **12** as shown in FIG. **1C**. The material present in the region of the thickened portion and around the margin of the hole **10** is under compressive pressure with a hoop stress and offers a considerable security against fatigue and crack formation in this region. The increased strength in this region as a result of the (fiber reinforced) thickened portion **52** is likewise favorable. The penetration of the component **12** by the tip takes place in such a way that only few reinforcement fibers are parted, so that a weakening in this region need not be feared. Furthermore, the tip **24**, on the increasing penetration of the component, presses the iris diaphragm, i.e. its diaphragm segments, progressively further open, so that its opening changes from the smallest opening **28** to the largest opening in accordance with FIG. **1B**. The movements of the individual diaphragm segments are synchronized by the tip favored by the compulsory guidance of the diaphragm segments as will be later explained in more detail.

After each piercing of a component the iris diaphragm or its diaphragm segments are reset from the largest opening **32** of FIG. **1B** to the smaller opening **28** in accordance with FIG. **1A**. This can eventually take place manually but best takes place through a suitable resetting device such as suitably arranged springs or the like (not shown).

A first embodiment of the design of an auxiliary aid (piercing aid) with an iris diaphragm **18** and an associated die button body **20** will now be described with reference to FIGS. **2A** to **2D**. In this connection features which are already described are characterized by the same reference numerals and it will be understood that the previous description for parts or features which have already been described also

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applies for the further figures and does not have to be repeated unnecessarily unless something contrary is stated.

As shown in FIG. **2B**, the piercing aid includes an iris diaphragm **18** with an upper plane having four diaphragm segments **60** which form a square opening **62** with a smaller initial opening **28** which can be pressed apart to a larger opening.

FIGS. **2E** and **2F** show the piercing aid in the closed state of the iris diaphragm **18** with the smaller starting opening **28** (FIG. **2E**) and show, also by means of arrows, how the diaphragm segments can be pressed apart by means of the tip **24** to the larger opening **32** of FIG. **2F**.

The iris diaphragm shown in FIGS. **2A** to **2F** has eight movably arranged diaphragm segments **60** which are arranged in two planes.

As is also evident from FIGS. **2C** and **2D** the four lower movably arranged segments **60** are arranged in a square mount **62** of a die button body **64**. At the center of the die button body, or of the mount **62** there is a bore **66** having a diameter which is fractionally larger than the diameter of a cylindrical region of the tip **64**. The sides **68** and **70** of the diaphragm segments **60** slide at the side of the side surfaces **72**, **74**, **76** and **78** of the mount and the diaphragm segments are guided by the side surfaces. The diaphragm segments **60** of FIG. **2C** form at their mutually confronting sides a square opening **80** the size of which can be made smaller or enlarged by displacement of the diaphragm segments **60** in one or another direction in accordance with the double arrows. The square opening **80** and also other square parts and features in the FIGS. **2A** to **2F** appear to be rectangular. This is however only to be attributed to the perspective representation.

The further four diaphragm segments **60** of FIG. **2B** which are arranged in a second square mount **82** of a disk **84** (FIG. **2A**) are formed, in plan view, in accordance with the diaphragm segments of FIG. **2C** but have at the upper side shoulders **86** which are arranged beneath the disk **84** and are able to slide at its underside. The level of the step formed by the shoulder **86** corresponds to the thickness of the disk **84**. The size of the square opening **82** of the disk **84** is somewhat smaller than the size of the square mount **63** of the die button body **64**. The disk **84** is screwed to the die button body at the points **88** by means of four counter sunk bolts. The disk **84** has the same diameter here as the die button body **64** could, however, also be made smaller and arranged in a recess manner in a circular recess in the end face of the die button body **64**.

One can see from FIGS. **2A** and **2D** that the disk **84** is rotated by 45° relative to the die button body **64** and the mount **82** is rotated by 45° relative to the mount **74**. In this way the square opening **90** of the upper diaphragm segments **60** is rotated by 45° relative to the square opening **80** of the lower diaphragm segments whereby an octagonal hole results in the assembled state. As can be seen from FIG. **2F** this represents a good approximation to a circular cross-section of the tip **24** and prevents matrix material escaping downwardly to a significant extent in the axial direction.

The diaphragm segments are secured against loss, but are guided displaceably within the mount **82** by the shoulders **86** provided at the outer sides of the upper plane of the diaphragm segments **60** which lie beneath the disk **84**.

The diaphragm segments of the iris diaphragms are respectively biased into a position in which they form the smaller starting opening. For this purpose, springs can be provided which act in the arrow directions of FIG. **2F**. A spring bias of this kind could also be achieved by a ring spring which surrounds the diaphragm segments or, for example, by individual arcuate leaf springs which are arranged between the

sides **68** of the diaphragm segments and the oppositely disposed wall regions of the mount **62** or **82** respectively.

The sidewalls of the mounts **62** and **82** form a type of compulsory guide or synchronization device which ensures that the diaphragm segments move synchronously, above all during the resetting movement but also during the hole formation.

The result of the above-described embodiment is to be seen in the fact that the diaphragm segments **60** lie in a first plane and in a second plane, in that the diaphragm segments **60** of the first plane (FIG. 2B) form a substantially polygonal hole **90**, in that the diaphragm segments of the second plane (FIG. 2C) likewise form a substantially polygonal hole **80** and in that the polygonal hole **90** of the first plane is offset angularly by one half side length of the polygonal hole **90** relative to the polygonal hole **80** of the second plane.

Furthermore it is evident that each diaphragm segment **60**, apart from rounded corner regions, has five straight sides, with three sides jointly forming two enclosed angles of 90° each and the two further sides forming a V-shape, likewise with an enclosed angle of 90°, with the two further enclosed angles of the diaphragm segments each being of 135°. Attention should also be paid to the fact that the diaphragm segments must have a certain lateral clearance between the sidewalls of the respective mounts **62** and **82**, as is evident from FIGS. 2A and 2F in order to ensure the required mobility. The diaphragm segments **80** of the first plane slide on the diaphragm segments of the second plane and these in turn slide on the base surface of the mount **62**.

Not shown in the Figures is a heater, whereby the component can be held at or can be heated to a matrix material dependent temperature, at least in the region of the piercing at which the matrix material of the composite material is not melted, but rather softens or becomes pasty, for example, heated to a temperature of 260° C. when the material is PA6. This heater can hold the tip **24** and the support **20** at the required operating temperature.

The tip **24** can be a tip which is specially used for the piercing process and which is repeatedly useable. It can, however, also be formed by a tip which is part of a bolt element and which can, for example, be present at the free end of the shaft part of the bolt element, as is described in the simultaneously filed German patent application of the present applicants with the attorney's file reference P10445PDE, the content of which is hereby made part of the content of the present application. Since each bolt element has its own tip it is not reused for a piercing process because the bolt element is subsequently connected in a form-fitted manner to the component and is in principle not separable from it. Furthermore, the tip can be formed by an auxiliary tip which is used with a hollow element such as a nut element as in the simultaneously filed German patent applications of the present applicant with the attorney's file reference P10443PDE and P10446PDE, the contents of which are hereby made part of the content of the present application. An auxiliary tip of this kind can also be used, for example, when it is a type of preceding hole punch or is only loosely inserted into the central passage of the hollow element. Alternatively, it can be a disposable auxiliary tip which is disposed of after the piercing process. Such disposable auxiliary tips can eventually be collected and sent back to the factory for the hollow elements where the tips can be reused, whereby unnecessary waste is avoided.

A particularly favorable embodiment of the invention will now be described with reference to FIGS. 3A to 3C and 4A to 4C. In these Figures the same reference numerals are used for parts or directions as used before in connection with the

FIGS. 1A to 1C and 2A to 2F and it will be understood that the previous explanation of these parts and directions also applies for the embodiments of FIGS. 3A to 3C and 4A to 4C, unless something is stated to the contrary. This convention also applies for the entire description.

The piercing aid is used, as is shown in FIGS. 4A to 4C, in the form of the die button with iris diaphragm **18** in combination with a tip **24** which is either formed by the free end of the shaft part of the bolt (not shown) or as an auxiliary tip **24** as is shown in FIGS. 3A to 3C. As can be seen from the FIGS. 4A to 4C the cross-sectional shape or the cross-sectional size of the tip of the auxiliary tip **24** in the longitudinal direction of the tip or the auxiliary tip is always matched to the respective cross-sectional shape and cross-sectional size of the widening opening **28**, **32** of the iris diaphragm. The auxiliary tip is shown per se in FIGS. 3A to 3C while the combination of the iris diaphragm **18** as such is shown in three different phases of the piercing process—however, without the composite material—in FIGS. 4A to 4C. In the embodiment of FIGS. 3A to 3C the tip or the auxiliary tip **24** has approximately the shape of a duck bill. Each cross-section perpendicular to the longitudinal direction **22** of the auxiliary tip **24** is formed by two overlapping circular arcs with the degree of the overlapping in the longitudinal direction **22** of the auxiliary tip progressively increasing starting from the smallest end in accordance with the degree of overlap of the two circular holes **61A** and **61B** of the plates **60A** and **60B**. At the position **94** of the full overlap of the auxiliary tip **24** then has a circular cross-section with a diameter equal to or slightly smaller than the diameter of the circular holes **61A** and **61B** of the two plates **60A** and **60B** respectively.

As can be seen from FIGS. 4A to 4C the matching of the cross-sectional shape and the cross-sectional size of the tip **24** to the cross-sectional shape and the cross-sectional size of the opening **28**, **32** of the iris diaphragm **18** takes place in such a way that independently of the degree of penetration of the iris diaphragm **18** by the tip or the auxiliary tip the cross-sectional shape and cross-sectional size of the tip of the auxiliary tip **24** the area of the opening **28**, **32** of the iris diaphragm **18** always corresponds to the cross-sectional shape and cross-sectional size of the respective opening **28**, **32**.

In the specific embodiment of FIGS. 4A to 4C the iris diaphragm **18** is equipped with two diaphragm segments **60A** and **60B** which are each formed by a plate having a circular hole **61A** and **61B** respectively, with the one plate **60A** being capable of sliding on the lower plate **60B**.

In the state shown in FIG. 4A the free end **26** of the auxiliary tip lies in the smallest opening **28** of the iris diaphragm which is formed by the overlap of the circular hole **61A** of the upper plate **60A** and of the circular hole **61B** of the lower plate **60B**. One notes that there are no free ends or other free regions through which the material of the composite material can escape.

The composite material is not shown here, however lies in accordance with FIG. 1B on the upper side of the iris diaphragm. The two plates are movable away from one another with increasing penetration of the tip in the arrow direction **92A** and **92B** starting from the starting position of FIG. 4A, for example, via the middle position in accordance with FIG. 4B into the end position in accordance with FIG. 4C. One sees that in the position of FIG. 4B there are likewise no free corners or other regions between the opening formed by the enlarged overlap of the plates of the iris diaphragm **18** and the respective cross-section of the auxiliary tip **24** in the region of the opening. This also applies to the end position in accordance with FIG. 4C in which the circular region of the auxiliary tip fully fills the circular opening in the two plates which

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are now fully aligned with one another and also for all intermediate positions between the position of FIG. 4A and FIG. 4C. The plates 60A and 60B can be reset from the position of maximum overlapping in accordance with FIG. 4C in the opposite arrow directions 92A' and 92B'.

As the relative movement of the two plates merely takes place in accordance with the arrows 92A, 92B, 92A' and 92B', only in one direction and in the opposite direction, the guidance of the two plates can be brought about very simply. For example, the thicker lower plate 60B can be guided in a flat longitudinal groove (not shown) in the free end face of a die button body (likewise not shown but similar to the die button body 64) and the upper thinner plate 60A can be guided in a corresponding flat groove in lower side of a cover disk (also not shown, but similar to the cover disk 84 of FIG. 2A) which is secured to the die button body 64, for example, by means of screws as are indicated at 88 in FIG. 2A.

The resetting of the two plates is also particularly simple to realize since the resetting device or the spring only has to act in one direction. It would also be conceivable to use two strips or recirculating belts instead of two plates which are provided with a plurality of circular holes such as 61A and 61B and which after each stroke of a possibly used press are transported further by one hole pitch in order to cooperate with an auxiliary tip. For each stroke of the press, a new component will be pierced when a hole forming the same component which is displaced between the strokes.

Finally it should be pointed out that the concept of using a tip or an auxiliary tip 64 of which the cross-sectional shape or cross-sectional size is matched to a shape and size of the opening of the iris diaphragm 18 is in no way restricted to the iris diaphragm 18 with only two diaphragm segments, but rather can in principle be used with all possible designs of an iris diaphragm with three, four or more diaphragm segments.

## REFERENCE NUMERAL LIST

10 hole  
12 component  
14, 16 sides  
18 iris diaphragm, piercing aid  
20 support, die button  
22 axial direction, longitudinal direction  
24 tip, auxiliary tip  
26 free end of the tip or of the auxiliary tip 24  
28 smaller opening, starting opening  
30 narrow region  
32 larger opening  
34 end face  
36 diaphragm segments  
38 arrow direction  
40 tool  
42 local upper side  
44 hold-down member  
46 lower end face  
48 cylindrical region  
52 thickened portion

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60 diaphragm segments  
60A plate, diaphragm segments  
60B plate, diaphragm segments  
61A circular opening of the plate 60A  
61B circular opening of the plate 60B  
62 square mount, opening  
64 die button body  
66 bore  
68, 70 sides  
72, 74, 76, 78 side surfaces  
80 square opening  
82 mount  
84 disk  
86 shoulder  
88 positions  
90 polygonal hole  
92A direction of movement of the upper plate 60A  
92B direction of movement of the lower plate 60B  
92A' opposite direction of movement of the upper plate 60A  
92B' opposite direction of movement of the lower plate 60B  
94 position of the auxiliary tip 24 with maximum overlap of two circles

The invention claimed is:

1. A method for the manufacture of a hole (10) in a component (12) consisting of a composite material, wherein the component (12) having first and second oppositely disposed sides (14, 16) is placed with its first side (14) on a support (20) having an iris diaphragm (18), wherein a tip (24) which diverges in the axial direction (22) is pressed coming from the second side (16) of the component (12) through the component (12), which optionally has a pre-piercing, for the formation of the hole (10) or for the enlargement of the pre-piercing and wherein the iris diaphragm (18) has a smaller starting opening (28) which receives a narrower region of the tip and opens into a larger opening (32) with increasing penetration of the component by the tip.
2. A method in accordance with claim 1, wherein the composite material is one of a fiber reinforced plastic part and a fabric reinforced plastic part.
3. A method in accordance with claim 1, wherein the iris diaphragm (18) forms part of a die button (20) received in the support, an end face of which facing the first side (14) of the component (12) is either flush area-wise with the local plane of the support (20) or is arranged set back from the local plane of the support (20).
4. A method in accordance with claim 1, wherein the iris diaphragm (18) is reset to the smaller opening (28) from the larger opening (32) after each piercing of the component (12).
5. A method in accordance with claim 1, wherein the component (12) is heated, at least in the region of the piercing to a matrix material dependent temperature at which the matrix material of the composite material does not melt but rather softens or becomes pasty.
6. A method in accordance with claim 5, wherein the component (12) is heated to a temperature of 260° C. when the material is PA6.

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